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Contents

- 2 Contributors
- 2 Science Council Contact Information
- **3** ATASC Executive
- 7 President's Message
- 8 Editor's Message
- **10** Supporting Metacognitive Development in Science Education: Exploring Ontario Elementary Teachers' Beliefs and Practices in Metacognition *Heather Braund*
- **22** Applying Utility-Value Writing Prompts to Science Education *Lia M Daniels and Lauren D Goegan*
- **28** Imagining Possible Futures with Science Fiction: *Doctor Who* and the Classroom *Catherine van Kessel and Monica Chahal*
- **35** Student Talk and Learning in Science *Jeff Turner*
- **37** Book Review: *Cheating Lessons: Learning from Academic Dishonesty*, by James M Lang *Kerry Rose*

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Contributors

Heather Braund is currently a full-time doctoral student in the Faculty of Education, University of Alberta. She graduated in 2014 with a bachelor of education from Queen's University, Kingston, Ontario, and is certified to teach primary and junior students. She holds an honours bachelor of science from Trent University, Peterborough, Ontario, with joint majors in psychology and biology. She has experience conducting quantitative research in breast cancer, aquatic biology and emergency medicine eye-tracking labs. She gained experience with mixed-methods research through her MEd study, titled "Supporting Metacognitive Development in Early Science Education: Exploring Elementary Teachers' Beliefs and Practices in Metacognition," supported by the Social Sciences and Humanities Research Council of Canada. Her doctoral research is now focused on bridging kindergarten teachers' classroom assessment practices with metacognitive development and self-regulated learning behaviours in kindergarten students.

Monica M Chahal is an adjunct professor with the Faculty of Education at the University of Alberta. Born and raised in Edmonton by hard-working, immigrant parents, she was encouraged to chase her dreams and passions. While working full-time at an inner-city school in London, England, she became inspired to want to make education more inclusive and accessible for marginalized youth.

Lia Daniels is an associate professor in the Department of Educational Psychology at the University of Alberta. Her research interests involve supporting preservice and practising teachers in developing optimally motivating learning environments. She is the director of the Alberta Consortium for Motivation and Emotion (https://sites .google.com/ualberta.ca/acme/home).

Lauren Goegan is a doctoral student in the Psychological Studies of Education program at the University of Alberta. Her research interests involve understanding the motivation of students with learning disabilities to best enhance their opportunities for success in school.

Kerry Rose was a high school science teacher in Sherwood Park, Alberta, for 30 years. She is presently completing her PhD in the Department of Secondary Education at the University of Alberta, where she teaches the introductory professional term (IPT) and advanced professional term (APT) science curriculum courses. At the Centre for Mathematics, Science and Technology Education (CMASTE), Kerry liaisons with schools, funding agencies, government departments and academics to coordinate science education projects locally, nationally and internationally.

Catherine van Kessel is an assistant professor in the Department of Secondary Education at the University of Alberta. Her research and interests include curriculum theory and how we might teach for social change.

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ATASC Executive



Carryl Bennett-Brown President

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Carryl began teaching in 2001, in Ponoka, Alberta. This was the best way to start teaching, because she was surrounded by a group of committed educators who cared deeply for children and were will-

ing to share their time, their knowledge and their skills. Currently, she is teaching in St Albert, at École Secondaire Sainte Marguerite d'Youville, while also being very involved in ATA activities—president of Local 23, secretary of NCTCA and formerly the secretary of ATASC. She is so pleased to become president of ATASC because it allows her science geekiness to thrive while providing professional development for the science teachers of Alberta.



James Slattery Vice-President

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James comes from a family of teachers and was born and raised in Fort McMurray. He graduated from the University of Alberta and taught in Fort McMurray, and now teaches in Edmonton. Involved in

several capacities with the Alberta Teacher's Association, he joined the Science Council executive in 2017 in the hope of helping expand the council's work to provide support to science teachers across the province.



Kari Lagadyn Treasurer

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Since 1998, Kari has spent her time teaching in the same French immersion school in St Albert where she did her last round of student teaching. She has taught almost every science class from Grade 8 to Grade 12, except for Biology 20 and Biology 30, and every junior high and senior high math course at one time or another. For much of her time out of the classroom she is an energetic soccer mom.



Brenna Toblan Executive Secretary brtoblan@cbe.ab.ca

Brenna turned to an education degree after completing her degree in astrophysics and physics because she needed a way to pay off her student loans and continue to a graduate degree.

Imagine her surprise when she not only enjoyed teaching, but also seemed to be reasonably good at it. Twenty-two years later, all but one spent teaching physics and chemistry at Central Memorial High School, in Calgary, she's developed a passion for getting students to think about how we know the things that we know, and to look at the world around them with a scientifically critical eye. She spends her nonteaching time (yes, there really can be such a thing) involved in science fiction in all media, and assorted geekery such as potions classes for kids at the Calgary Comic Expo. At Science Council meetings she can be found behind her screen, typing up a storm and inserting assorted parenthetical comments into the minutes.

Alicia Taylor Conference Director 2019 sweetleesh1@yahoo.com

Alicia has been teaching since 2004 and has had the opportunity to teach students both in the classroom and online. She now calls Calgary home and teaches chemistry, mathematics and science at Queen Elizabeth High School. She also has a role with her ATA local PD committee and serves on the local council of school representatives. After her work on the Science Council's 2017 conference, she is looking forward to working as the conference director for 2019.

Pauline Law Assistant Conference Director 2019 plaw02019@gmail.com

Pauline began teaching in 2001, and has been teaching with Edmonton Public Schools since 2006. She is currently with Hospital School Campuses as the junior and senior math and science teacher at the Royal Alexandra Hospital Classroom. Pauline loves to travel, and when presented with the opportunity will spend hours in science museums. Her top three most memorable exhibits so far were seeing a pair of Gregor Mendel's glasses, Robert Hooke's microscope and Richard Feynman's bongo drums. Pauline is excited and ready to work with the ATA Science Council executive to help put together an engaging, retro-inspired Science Council conference in 2019.



Tracy Onuczko Past Conference Director (2018)

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Tracy has been teaching science, mainly biology and general science, in K–12 schools and to preservice teachers at the University of Alberta since 2005. She

is currently completing her PhD in science education at the University of Alberta. Tracy is thrilled to be part of ATASC and is looking forward to helping with this year's conference.



Deepali Medhekar Technology Director

Deepali started her teaching career as a science teacher and teacher educator in Vadodara, India. She moved to Canada in 2005, and achieved her Alberta teacher certification. She has taught science in both countries in the formal school systems as

well as in nonformal science education centres such as Eklavya and Telus World of Science. She is passionate about inquiry-based learning by doing in science and likes to infuse technology in her teaching practice. She believes in the power of volunteering as a means of feeling connected to her community. Jennifer Hopkins Newsletter Editor Biography not available.



Monica Chahal Journal Editor

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Born and raised in Edmonton by hard-working, immigrant parents, Monica was encouraged to chase her dreams and passions, one of which is a love of science. While working full-time at an

inner-city school in Westminster, London, she became inspired to want to make education more inclusive and accessible for marginalized youth, and pursued graduate studies as a result. She is an avid science fiction fan and believes in the power of the Doctor—bow ties are cool. She is currently an adjunct professor with the Faculty of Education of the University of Alberta and a science teacher at Centre High, in Edmonton.



Peter Rehak Elementary Director

Peter Rehak has been teaching Division II and III students for 22 years. He started in a rural school, teaching Grades 4 to 6 in the morning and junior high in the afternoon. Being flexible and proficient in multiple subject areas was a necessary skill to

quickly develop. Inspiring and promoting self-discovery have been mainstays of his lessons. "Using and abusing" technology and science in the classroom has come naturally to him while helping students identify and develop their passions.

Amanda Joblinski Division III Director ajob1@telus.net

Amanda began teaching in 1999 with a bachelor of education and has taught a variety of subjects over the years, but has primarily taught Grades 5 to 9 science. During this time, Amanda completed a diploma of education in curriculum studies (science and social studies) and a master of education in administration and leadership (policy studies). Travelling with students to explore science and being involved with different aspects of the science education community are both passions that take up all of her time that isn't spent in the classroom or with her two little boys.

Rekha Dhawan

Division IV Director

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Rekha has been an educator since 1989 and has taught in Calgary since 2003. She enjoys teaching high school chemistry, biology and general sciences, and is always looking for ways to connect sciences to life. She tries to build inquiry into all her teaching. Her other passion is cooking up new recipes in the kitchen, incorporating several international cuisines. She loved teaching Domestic Foods 10/20/30 and organizing sessions to induce her friends and colleagues to try out newly created recipes. She is completing her doctorate in education, leadership in education, at Werklund School of Education, University of Calgary. Before taking on the role of Division IV director, she had been the ATASC chemistry director since 2009; she thoroughly enjoys her latest passion, kickboxing.



Danika Richard Division IV Director

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Danika has been teaching for the past six years, primarily in high school biology, chemistry and general sciences. She is a certified yoga instructor and offers a yoga option for high school

students as a locally developed course. As a former entomologist, she shares her love for insects with her students (and anybody else who is too polite to tell her to stop) and tries to incorporate this passion as much as she can into her lessons. She loves gardening and, despite her athletic abilities, enjoys playing on various recreational sports teams.



Kerry Rose Postsecondary Director kerryr@ualberta.ca

Kerry Rose was a high school science teacher in Sherwood Park for 30 years. She is presently completing her PhD in the Department of Secondary Education at the University of Alberta,

where she teaches the introductory professional term (IPT) and advanced professional term (APT) science curriculum courses. At the Centre for Mathematics, Science and Technology Education (CMASTE), Kerry liaisons with schools, funding agencies, government departments and academics to coordinate science education projects locally, nationally and internationally. If you have ideas for projects or are interested in finding out more about CMASTE, please get in touch! Follow CMASTE on Facebook for upcoming projects, speakers and events.

Genevieve Payeur Member at Large Biography not available.

Bernice Pui

Member at Large

Bernice has been teaching for the past six years, primarily in high school advanced placement biology, chemistry, general sciences, and speech and debate, with a diverse group of students. She is currently completing her master of education in educational studies while working full-time, and loves the interplay between learning and being able to implement her learning in her classroom. Bernice has been involved with the ATA Science Council for the last three years and the Science Curriculum Working Group (CWG) for the last two years. Furthermore, she is the educational technology high school leader at her school and is always looking for ways to effectively implement technology in the classroom. She loves continuing her lifelong learning and always finding ways to see the spark in students when that lightbulb moment happens.



Leon Lau Acting Past President lhlau@cbe.ab.ca

Leon holds an MSc from the University of Alberta and has been a classroom teacher for 10 years. He is driven to advance science education and has volunteered with Science Council and

ATA Local 38 for 7 years. Leon has also contributed to the Science 30 diploma exam and the current curriculum development process. Outside of school, he enjoys hiking, skiing, curling and social dancing.



Sean Brown Executive Staff Officer

Sean joined the Association's Teacher Welfare executive staff in 2015. He holds a BEd from the University of Alberta, a master of educational technology from the University of British Columbia and a graduate certificate in Catholic school administration

from Newman Theological College. Sean began his teaching career with Grande Prairie and District Catholic Schools, where he taught for 5 years. He also taught for 16 years with the Greater St Albert Roman Catholic Schools, 5 of those years as a vice-principal. In addition to acting as a representative of the bargaining agent, Sean acts as the Association's expert in the area of education finance and is the staff advisor for the Science Council. Provincially, Sean served as district representative for Edmonton District for 2 years and as an economic consultant for 8 years. At the local level, he served as president, vice-president, EPC/NSC chair and several other positions with Greater St Albert Catholic Local No 23. **Paul Froese District Representative** Biography not available.



Wes Irwin

Alberta Education Liaison

Wes Irwin has worked in the field of science education with diverse groups of students for more than 30 years. Wes has worked as a junior/senior high school teacher, curriculum lead and, more recently, provincial curriculum manager. Over the years, Wes has

been heavily involved with the executive of the ATA Science Council, including one term as council president. In his current role with Alberta Education, Wes is working with teachers from across the province on the development of the K–12 provincial science curriculum.

President's Message

Carryl Bennett-Brown

Welcome back to another school term and learning about science! The Alberta Teachers' Association's Science Council is so appreciative of having a professional journal in which research and articles of a professional nature are presented and celebrated. This journal allows for diverse topics to be investigated and contributions from a variety of educators to be shared. With such critical science education and knowledge to be communicated, this journal can help us all support the values and beliefs of science. In addition, while examining current scientific issues as well as burgeoning and evolving science topics, society can learn to be comfortable in questioning the world that surrounds us. Further, it is essential for educators to be well versed in complex issues. With access to endless information on the Internet, which is not always based on research and sound practices, it is vital to have access to reliable data and strong facts.

Thank you for your contributions to education and to science.

Editor's Message

Monica M Chahal

Anyone who has never made a mistake has never tried anything new.

—attr Albert Einstein

Exceptional educators are always trying to improve their pedagogy through experimentation, which at times can lead to blunders. I am sure we have all had a lesson that just went wrong. However, as set out in the quote above, without mistakes nothing new is ever attained. As educators, we have the luxury and privilege of working in a subject bursting with those that have tried something new; thus, it makes sense that we take risks and make mistakes when we teach. We theorize, postulate and then, hopefully, conduct experiments and create pedagogical processes, all in the attempt of improving what has come before us. In my own career I have built upon Aikenhead, Apple, Bhabha, Blades and Said in a desire to improve my teaching practice. I ask you to ponder what has come before you, and then take risks and make mistakes.

Heather Braund's article, "Supporting Metacognitive Development in Science Education: Exploring Ontario Elementary Teachers' Beliefs and Practices in Metacognition," provides a guide for how to limit misunderstandings in the classroom by simply stating why we are doing what we are doing. Heather's article provides a brief synopsis on metacognition and explores what teachers know about metacognition and their beliefs about young children's abilities to be metacognitive while learning science. This is important as a Canadian study, but as an individual reader I was forced to reflect on my own notions of metacognition in the classroom. I realized that within my own practice I have experienced the power of explanation.

Lia M Daniels and Lauren D Goegan's article, "Applying Utility-Value Writing Prompts to Science Education," provides examples of how Alberta science teachers could retain or generate interest in science in our classrooms. This nonempirical paper highlights the theory behind the success of utility-value writing assignments, which represent a type of motivation intervention that has consistently demonstrated a positive effect on students' interest and performance in science. They describe the theory in their paper, but what is extremely useful is that they provide educators with concrete steps for writing and scoring utility-value writing assignments in their own junior and senior high science classrooms.

The article by van Kessel and Chahal discusses how science fiction can provide opportunities for crosscurricular exploration. The paper uses an episode of *Doctor Who* to connect future studies to praxis within the context of biology and ecology. The article provides educators with the opportunity to explore science fiction in the classroom as science fiction provides an opportunity to critique contemporary society. The episode "Gridlock" allowed us to explore a future in which science and technology in society have led to lethal drug use and dangerous air quality, but left us hopeful that a utopian society is possible.

In a desire to see how far we have come, I have included an article from the first issue of ASEJ, in 1993, by Jeff Turner. "Student Talk and Learning in Science" provides multifold highlights: first, the changes in academic articles in our journal over the past 26 years; second, an illustration that constructivism has been a part of science education for decades; and last, a recognition that talking is essential for learning to occur.

We continue with our book review feature (introduced in our last issue). Kerry Rose reviews *Cheating Lessons: Learning from Academic Dishonesty* (2013), by James M Lang. Unfortunately, as educators, we find that cheating is a part of our daily discourse. This book provides research into student academic dishonesty, but, more important, provides ways for teachers to support students and prevent them from making the mistake of cheating. For more details, make sure to read Kerry's review.

Once again, I thank all contributors to this journal authors, reviewers, copy editors and anyone that I have bounced ideas off. Writing is a great process to reflect and research new ideas. If you would like to review a book, please contact me at atascjournaleditor@gmail.com.

We all make mistakes, but never let a mistake hinder you. Remember that to fail is merely your first attempt in learning. I hope that you've used the summer to make even more mistakes, learn, discover, rejuvenate. Welcome to the new school year.

Supporting Metacognitive Development in Science Education: Exploring Ontario Elementary Teachers' Beliefs and Practices in Metacognition

Heather Braund

Abstract

Metacognition is the understanding and control of cognitive processes. This mixed-methods study examined elementary teachers' beliefs about metacognition and integration in science through the following research questions: (1) How do elementary teachers conceptualize metacognition? (2) What is the relationship between elementary teachers' beliefs about metacognition and their classroom practices? (3) How do elementary teachers integrate metacognition into their science lessons? In-service teachers were recruited through professional networks to complete a questionnaire titled "Student Metacognition in Elementary Science," which contained openended questions and Likert-type items. Additionally, five respondents completed semistructured interviews informed by the questionnaire. The Likert-type items were analyzed through reliability analysis, independent t-tests, and multiple (hierarchical) regression. All participants were grouped into veteran (n=19) or early (n=22) teachers. Regression analysis demonstrated that participants' actions and beliefs varied based on their years of experience but not their gender. Years of experience was significantly correlated with teachers' actions. Generally, teachers understood metacognition and were able to identify reflective thinking as the foundation for metacognitive thinking. However, some gaps remain in their conceptual understandings. Participants emphasized the need for explicit instruction and ongoing opportunities to practise metacognitive skills. Most participants believed that metacognition was appropriate for elementary students because the students had

the cognitive capacity to think metacognitively. A lack of consensus around the domain specificity of metacognition remains; all interviewees believed that metacognition was not domain specific, compared to more than half of the questionnaire respondents who held the opposite opinion. Participants reported struggling when their students were not explicit about their thinking. Professional development should focus on sharing new ways of measuring students' metacognitive thinking and making students' thinking visible to help support teachers.

Background and Rationale for Proposed Study

Metacognition is the understanding, awareness and control that an individual has over their cognitive processes (Flavell 1979; Papleontiou-Iouca 2003; Thomas 2011). Research demonstrates that students are more likely to be successful within and outside the classroom when they know how to learn and regulate their learning (Papleontiou-Iouca 2003; Zimmerman 2002). More specifically, students need to understand themselves as learners (metacognition) (Wilson and Bai 2010). Research has demonstrated that younger students struggled with metacognition and self-regulation during complex tasks (Winne 1997; Zimmerman 1990), with more developed metacognitive strategies and metacognitive knowledge developing around the ages of 8 to 10 (Rudd 1992). Zohar and Peled (2008) also demonstrated the importance of developing students' metacognition through explicit instruction on strategy use. They conducted an experimental study in which Grade 5 students were assigned to either the control or experimental group, with varying abilities across both groups. Both groups completed science lessons on seed germination and participated in interviews. An increase in strategy use and metacognition was found for both lower- and higher-achieving students in the experimental group.

Metacognition has traditionally been studied within literacy contexts with little extension across subjects, despite the well-documented importance of metacognition (Carrell, Gajdusek and Wise 1998; Pressley 2002; Wenden 1998). Furthermore, traditionally researchers and scholars did not believe that younger students had the cognitive capacity to think metacognitively; thus, research has tended to focus on older student populations (Williams and Atkins 2009). Due to the increased interest in studying metacognition within a science context, Zohar and Barzilai (2013) conducted a review of literature to determine trends and future directions with respect to metacognition in science. After synthesizing research trends, an area identified as requiring greater examination was teachers' perspectives on metacognition. More specifically, a greater understanding of what teachers know about metacognition, and their beliefs about young children's abilities to be metacognitive while learning science is needed. Before metacognition can be implemented across subjects, more knowledge is required about teachers' perspectives on metacognition within elementary science contexts (Thomas 2011; Zohar and Barzilai 2013).

Research Objectives

The purpose of this study was to examine elementary teachers' beliefs about metacognition and their integration within science. Three research questions guided this study:

- 1. How do elementary teachers conceptualize metacognition?
- 2. What is the relationship between elementary teachers' beliefs about metacognition and their classroom practices?
- 3. How do elementary teachers integrate metacognition into their science lessons?

Theoretical Perspective

Metacognition consists of three components: metacognitive knowledge, metacognitive regulation and metacognitive experiences (Efklides 2006; Flavell 1979). Metacognitive knowledge (MK) includes the thoughts and beliefs about an individual's cognitive capabilities (Efklides 2006; Flavell 1979). Metacognitive regulation (MR) includes the monitoring and control of one's learning (Flavell 1979). Successful learners control their learning through planning, monitoring and evaluating their learning (Zimmerman 2002). Finally, metacognitive experiences, a practical component for classroom practice, is understudied (Efklides 2006). This includes the affective experiences (judgments and feelings) that students have about their learning. These feelings may be of confidence, satisfaction, familiarity and so on (Ben-David and Orion 2013; Efklides 2006). These metacognitive experiences encourage students to make changes while learning (Efklides 2006; Nelson 1992).

These skills from all three components of metacognition are not innate in nature; they can be learned and further developed through explicit instruction (White and Frederiksen 1998). All three metacognition components are essential for success and should be developed together. The manner in which teachers help students to develop their metacognition includes practices such as modelling the use of metacognitive strategies, describing their thinking, planning their goals out loud, suggesting problem-solving methods and showing students how they can work through their thinking while talking out loud (Papleontiou-Iouca 2003).

Teachers' Perspectives on Metacognition

Ben-David and Orion (2013) explored 44 elementary science teachers' perspectives on integrating metacognition into science contexts in Israel. Participants attended a professional development (PD) program focusing on the science curriculum and engaged in metacognitive activities throughout the PD (p 3169). Participants generally had negative and skeptical views toward integrating metacognition before the PD program (p 3178). Their initial knowledge of metacognition had clear gaps and misconceptions, such as metacognitive thinking only being appropriate for high-achieving students (p 3181). Following the professional development program, participants were surprised at the importance and value of metacognition. They found metacognitive experiences to be the most valuable and practical. Participants' views toward integrating metacognition became more positive and complete (p 3186).

Wilson and Bai (2010) examined the relationship among teachers' metacognitive knowledge, pedagogical understanding and perceptions of how to teach students to be metacognitive. An online survey was completed by 105 MEd students in the United States. The findings suggested a significant relationship between metacognitive knowledge and pedagogical understanding of metacognition where the first impacted the later. Participants reported the need for a rich understanding of metacognition as part of developing students' metacognition (p 269). The participants also reiterated the need for explicit instruction and ongoing opportunities to practise when working to develop metacognition.

Zohar, Degani and Vaaknin (2001) examined the extent to which teachers held misconceptions about the development of metacognitive thinking. Following semistructured interviews, 45 per cent of teachers indicated that they felt metacognition was inappropriate for low-achieving students. This was believed to be the case because participants felt that low-achieving students would have increased levels of frustration when trying to engage in higher-order thinking tasks. Only 20 per cent of teachers reported that higher-order thinking was appropriate for students of both low- and high-ability levels.

Students' capabilities to develop their metacognition are shaped by their teachers (Paris and Paris 2001). Teachers need to have a thorough understanding of

Table 1

Demographic Information for Interview Participants

metacognition to help their students develop metacognitive thinking. Teachers also need to believe that students are cognitively capable of thinking metacognitively. The modelled strategies and skills must be of appropriate developmental levels for their students (Wilson and Bai 2010). Therefore, a greater understanding of what teachers believe about the construct and ways in which they integrate it within science must be determined.

Methods

This study used a sequential explanatory mixedmethods research design (Johnson and Onwuegbuzie 2004). Following appropriate ethical clearance, participants were recruited through STAO (Science Teachers Association of Ontario) and teacher network groups. An online questionnaire was administered to 44 Ontario elementary teachers, collecting demographics and teachers' perspectives on metacognition through original questions and from two modified scales: Teachers' Metacognitive Scale (Wilson and Bai 2010) and Self-Regulated Teacher Belief Scale (Lombaerts et al 2009). Following the four demographic and seven open-ended questions, there were 26 Likert-type items. These items ranged from 1 to 5 on a scale, with 1 representing strongly disagree and 5 representing strongly agree for each Likert-type item.

In phase two of the study, semistructured qualitative interviews were conducted with five practising elementary teachers in Ontario. The interview participants all had a minimum of three years' teaching experience in Ontario and were purposefully selected based upon their understanding of

Participant	Years of Experience	Education	Gender	Current Assigned Grade
Amanda	24	BA, BEd	Female	5
David	15	BSc, BEd, MEd	Male	7/8
Jacob	3	BSc, BEd, MEd	Male	1/2, 6 (French immersion)
Ben	18	MEd	Male	K
Anna	12	BSc	Female	7

metacognition and integration examples provided on the questionnaire. These interviews asked teachers to describe cases of integrating metacognitive teaching into elementary science lessons. The interviews also asked clarifying questions aimed at understanding teachers' beliefs about metacognition and conceptualization. Please refer to Table 1 for demographics for interview participants. All questionnaire responses were reported anonymously, and interviewees were assigned pseudonyms following ethical clearance protocols. The Likert-type items were analyzed through reliability analysis, independent t-tests and multiple (hierarchical) regression using SPSS (version 24). All participants completed the survey and were grouped into veteran (n=19;six or more years of experience) or early (n=22; zero)to five years of experience) teachers. The qualitative data were analyzed thematically. Data of both phases were integrated and analyzed together to maintain a mixed-methods approach. The significance level for all statistical analyses was set at 0.05.

Descriptive Statistics of Sample

Based upon the statistically analyzed responses (n=41), a larger portion of respondents had bachelor of arts degrees (69 per cent) while 31 per cent had bachelor of science degrees. Only 17 per cent of questionnaire respondents had master's degrees. Respondents for the questionnaire ranged in the number of years that they had been certified through Ontario College of Teachers. The mean number of years was 7.34, indicating that more experienced teachers tended to answer the questionnaire. Experience ranged from 0.5 to25 years, with 3 years of experience being the most frequent response (six respondents).

Reliability Analyses

An overall reliability analysis was run for all of the overall Likert-type items. Then the items were divided into two groups that conceptually resulted in beliefs or action items. The belief items focused on teachers' beliefs about metacognition. An item representative of beliefs would be "Metacognitive thinking is appropriate for intermediate and senior students (Grades 7–12)." The actions scale referred to actions that teachers executed to promote or integrate metacognition. An example of an item representative of teachers' actions would be "I consistently model what I am thinking for my students when I am working

through a problem, investigation or task in science." A second reliability analysis was run for the belief items and a third for the action items.

Inferential Analyses

Total scores were generated for each participant for each of the two subscales (beliefs and actions). Belief items focused on teachers' beliefs about metacognition, while action items focused on teacher strategies to promote metacognition. Independent t-tests were used to investigate the extent to which teachers' responses to the Likert-type items differed significantly according to their years of experience. A hierarchical regress analysis was used to explore the extent to which years of experience, gender and teachers' beliefs predicted their actions. The dependent variable was the total actions score entered in block 1. In block 1, experience and gender were entered as the independent variables; total beliefs was added in as an independent variable in block 2.

Qualitative Data Analysis

Following transcription, all documents were imported into Atlas.ti for analysis. The interviews were coded individually, and then coding was completed across the interviews. During individual coding, each coded segment was mapped onto the research questions to increase the likelihood that the coded data were relevant to the current research study. The codes were the smallest individual units of analysis. Preliminary coding of the first two interviews was completed and then discussed with the research team. The coding process was very iterative, because interviews were recoded following the preliminary coding and discussion. Codes that were similar were grouped together to generate larger themes across the qualitative data (open-ended questionnaire responses and interview data).

Results

For clarification, *respondents* are those that responded to the questionnaire (phase one), and *interviewees* are those that completed interviews (phase two). The word *participants* describes both interviewees and respondents. The overall reliability of the Likerttype questions was 0.884 for the 26 items (0.720 11item beliefs scale; 0.908 15-item actions scale). Seven key findings, listed below, emerged from both the questionnaire and interview data; a detailed elaboration follows.

- 1. Participants largely understood metacognition but had some gaps in their knowledge.
- 2. Participants' actions and beliefs varied based on participants' years of experience, but not their gender.
- 3. Participants discussed how metacognition can develop through explicit instruction, provided that students are given opportunities to practise these skills.
- 4. Participants discussed metacognition as if it should be conceptualized on a continuum, due to the wide range of metacognitive thinking that they had seen in their classrooms.
- 5. Interviewees believed that metacognition was not domain specific, compared to more than half of the questionnaire respondents, who believed it was necessary to teach different metacognitive strategies for different subjects.
- 6. Participants described how they taught specific strategies, generated strategies with students and posted them in the classroom. Participants also endorsed students learning from their peers.
- 7. Participants also connected metacognition to growth mindset.

1. Participants largely understood metacognition but had some gaps in their knowledge.

Participants generally conceptualized reflective thinking as a foundation for metacognitive thinking and reiterated the need for students to understand their strengths, needs and strategies. For example, one respondent described metacognition as "when students reflect back on their learning and examine when and how they learn best, so they can use these skills to improve their learning ..." Seventy-three per cent of respondents provided time for reflective thinking in science. Many participants reported accurate components of metacognition, including students needing to regulate and be aware of their thinking. For example, respondents knew metacognition's definition according to Flavell (1979), "thinking about your thinking." Metacognitive experiences were not mentioned at all. Yet, 49 per cent of respondents indicated that "I help my students understand how to use their feelings to positively impact their learning in science." Instead,

participants focused on metacognitive regulation and knowledge. The awareness and understanding of an individual's thinking were the most frequently reported components (35 per cent) when participants described metacognition. Strategy use was reported by 17 per cent of participants, alongside components of self-regulated learning (planning, monitoring and evaluating).

All five interviewees and some participants reported that metacognition was foundational and important for students for a variety of reasons, including that it resulted in more successful and effective learning (n=10) and encouraged students to take ownership and be responsible for their learning (n=5). Being metacognitive places students at the centre of the learning process, as described by a respondent: "When you think about your learning processes, you become more aware of what works for you. Students can become aware of their own needs, advocate for themselves and become generally more responsible for their own learning." Participants also discussed how metacognition included an understanding of strengths and weaknesses. Metacognition was also linked to selfregulated learning, as described by Jacob: "One of the more valuable ... tools for children, students and teachers for learning ... self- regulation and metacognition I think are ... the two biggest things that kids should do in class ... So those two I think are very, very important." While 95 per cent of all participants had positive beliefs about metacognition, one respondent was asked to comment on the importance of metacognition and responded, "limited, unimportant."

Despite teachers generally understanding facets of metacognition, a small subset of participants expressed inaccurate and unclear understandings of metacognition. Specifically, three respondents and one interviewee emphasized making real-world connections as part of metacognition, but it was unclear how this conceptually supported metacognition. *Metacognition* and *higher-order thinking* were also used interchangeably by three respondents and one interviewee, demonstrating a lack of understanding.

2. Participants' actions and beliefs varied based on participants' years of experience, but not their gender.

Pearson correlations are located in Table 2. Years of experience was significantly correlated with teachers' actions, r=0.337, n=41, p<0.05. Teachers' beliefs

		Experience	Total Deneis	
Gender				
Years of Experience	.076			
Total Beliefs	.087	.225		
Total Actions	.154	.337*	.651***	

 Table 2

 Pearson Correlation Coefficients for Gender, Years of Experience, Teacher Beliefs and Actions (n=41)

* p < 0.05, ***p < 0.001

and actions were significantly correlated, r=0.651, n=41, p<0.001. A significant difference using t-tests was found between early (M=2.03, SD=0.415) and veteran teachers (M=2.28, SD=0.290) and their actions, t(39)=-2.234, p=0.028, d=0.71 constituting a medium effect size.

Hierarchical multiple regression was used to determine if gender, experience and teachers' beliefs predict teachers' actions (Table 3). Gender and experience were entered at step one, explaining 13 per cent of the variance; however, this was not significant (R^2 =0.130, p=0.071). Teacher beliefs was entered in step two, and explained 33.9 per cent of the variance, R^2 =0.339, F(2, 37)=23.665, p<0.001. In the final model, only the total beliefs variable was significant (β =0.599, p<0.001) compared to gender (β =0.087,

Table 3 Summary of Multiple Regression

p > 0.001) and years of experience ($\beta = 0.195$, p > 0.001). Although the first block of gender and experience was not a significant predictor of teachers' metacognitive actions, experience was a significant predictor by itself. Experience was not a significant predictor once *teacher beliefs* was added.

Generally, veteran teachers reported increased frequency of encouraging the use of planning, monitoring and evaluation strategies. More specifically, the vast majority of veteran teachers (89 per cent) indicated that "I help guide my students through planning their learning in science," compared to 70 per cent of early teachers. Only 65 per cent of early teachers indicated that "I help guide my students through monitoring their learning in science," in contrast to 84 per cent of veteran teachers.

	Model 1		Model 2	
	ß	t	ß	t
Gender	.129	.847	.087	.721
Experience	.327*	2.155	.195	1.585
Total Beliefs			.599***	4.865
R ²	.13		.469***	
R ² change			.339***	

* p < .05, ***p < .001

3. Participants discussed how metacognition can develop through explicit instruction, provided that students are given opportunities to practise these skills.

Participants also discussed how metacognition can develop through explicit instruction, provided that students are given opportunities to practise these skills. After combining responses for *strongly agreed* and *agreed*, 97 per cent of respondents believed that metacognition developed with practice. During his interview, David discussed explicit instruction, "setting them up for success is modelling it." Ben emphasized that for kindergarten, metacognition "has to be all the time everywhere. They have to be immersed in it …"

4. Participants discussed metacognition as if it should be conceptualized on a continuum, due to the wide range of metacognitive thinking that they had seen in their classrooms.

Three respondents reported a misconception that metacognitive thinking was only appropriate for highachieving students, and two respondents reported that it was more appropriate for older students. One respondent discussed the importance of metacognition, "for some ages yes, for early primary K to 2, no. It may help the older students to understand how they learn."

However, given these beliefs, 95 per cent of respondents indicated that children in kindergarten to Grade 3 were capable of thinking metacognitively. Ben provided direct examples of ways in which he integrated metacognition into his kindergarten classroom. He even used the term *metacognition* with his students, because he believed that young children could be metacognitive but "they're not ready for deeper levels of metacognition." These differences in metacognitive abilities were discussed across grade levels and within several teachers' classrooms. Jacob described the range of abilities in his classrooms: "Some students would be very effectively using metacognitive strategies and even be able to name it. But then other students definitely would not know what we're talking about or wouldn't be using any of those strategies." These differences may be as a result of students' cognitive abilities, as described by Anna: "... I think that everybody can do it at some level. But some students are not cognitively ready to do it in exactly the same way as others." Despite the differences in metacognitive

thinking, interviewees discussed how some of their students were able to think metacognitively without any prompting, almost as if these strategies were automatized. Anna elaborated, "Some are very at ease and think about their own thinking by themselves. ... I wouldn't even have to do the exercises, they do it themselves. They think back and said, 'Oh, okay, I could have improved this,' even without me prompting them."

5. Interviewees believed that metacognition was not domain specific, compared to more than half of the questionnaire respondents, who believed it was necessary to teach different metacognitive strategies for different subjects.

The majority of respondents (62 per cent) reported that it was necessary to teach different metacognitive strategies for different subjects. Jacob discussed how he thought most about integrating metacognition into science. "With math, it's easier to focus on flash cards and repetition. Since I don't teach reading or literacy, I haven't had to use anything there. So, it's mostly science that I think about metacognition the most in." Interviewees discussed how they used a strategy in literacy or math and then thought about how to use it in science.

6. Participants described how they taught specific strategies, generated strategies with students and posted them in the classroom. Participants also promoted students learning from their peers.

Figure 1 demonstrates the most commonly used strategies when integrating metacognition into science. Respondents used modelling (80 per cent), "think alouds" (71 per cent) and reflection (73 per cent). The interviewees indicated that explicit instruction on metacognitive thinking was necessary. They prompted their students to think while learning and monitor their strategies, and guided them through reflective thinking.

Despite metacognition being an individualized process, participants commonly discussed the use of strategy sharing among peers as a way to develop students' metacognition. Ben talked about how his kindergarten students were really encouraged to learn from each other despite their young age. "I would say



Figure 1: Different strategies that teachers use to support student development of metacognition

also the peer-to-peer teaching of metacognition is not just dependent on me. ... I don't want them to depend on me. I want the class to take ownership so they can help each other." Interviewees discussed how they would still make the learning explicit for students by drawing students' attention to strategies used by peers.

The importance of dialogue was also discussed as participants reported that students learned through ongoing dialogue. Anna discussed her experiences with dialogue: "I think listening to each other, they can compare and say okay, well I didn't do that but that's interesting. Maybe I could change it and do it like they're doing it." Anna elaborated further, explaining how peer assessment helps students to consider other perspectives, "so they can assess themselves and then there is a column for a peer to check if they've done that. And if both agree and they've completed everything then they can hand it into the teacher. We do that also for oral presentations. So they sort of [use] a mini rubric and they self-assess where they think they are and they get a peer to assess their presentation before they would present to the class." Dialogue was used at varying grade levels as a tool to promote metacognitive thinking. Further, Ben emphasized the critical

role that dialogue played in his kindergarten classroom. "The more metacognitive strategies and thinking I've brought into my classroom, the higher the level of dialogue and the higher the level of ... interest in asking ... and exploring questions. And like I said, most of those questions are science based." Ben elaborated further by explaining how he points out when students are learning from each other, "Dialogue is an important tool. When I've figured out that they've learned something from a peer, I'll point it out. I said 'Oh, you got that from you know, I see that you took so-and-so's idea and you know, you expanded it or used it in your own way.' Until they ... develop a culture of dialogue, the important part of learning and they have to understand 'Ok, this is something I do to learn—I talk to other people. I listen to other people. I try out their ideas. I expand on them, etc."

7. Participants also connected metacognition to growth mindset.

Two interviewees and five respondents discussed explicitly how they encouraged their students to have growth mindsets. Other participants hinted at this but did not use the same terminology of *growth mindset*. All interviewees discussed the need to promote a positive learning culture to help support the development of students' metacognition. A respondent connected metacognitive thinking to growth mindset: "Students who are self-aware are better able to maintain a growth mindset toward learning ... they can identify what they did well and what they need to improve. This way they don't shut down and decide they ... aren't good enough." In the primary and junior high settings, encouraging students to maintain a positive attitude toward learning and promote a growth mindset was reported as a critical factor to help develop metacognition. Participants also discussed the need to value mistakes in their classrooms as a tool to enhance students' metacognition. Interviewees discussed how this had to be introduced on day one so that students understood the importance of making mistakes and learning from them, a crucial component of a growth mindset.

Discussion

Participants were able to identify key components of metacognition, such as reflective thinking, metacognitive awareness and understanding one's strengths. In this respect, participants tended to focus on metacognitive regulation and metacognitive knowledge. No participant mentioned metacognitive experiences, and a subset of participants displayed noticeable gaps in their understanding. These findings suggest that participants could benefit from clarification and further education surrounding metacognition.

Generally, participants from the current study did not express such skepticism or negativity towards integrating metacognition within science when compared to participants from Ben-David and Orion (2013). The difference in the findings (Table 2, page 15) may be a result of varying education initiatives or preservice education training. In the current study, about 38 participants seemed to have the foundational bases for understanding metacognition. This foundational knowledge included indicating that it was the awareness of how an individual learns, relating it to understanding your strengths and weaknesses, and reflective thinking. However, participants in both studies clearly demonstrated some gaps and misunderstandings surrounding metacognition. The misconception that metacognition is only appropriate for high-achieving students was present in the current study, although to a much lesser extent when compared to the views from Israeli teachers. The biggest gap in knowledge about metacognition existed in the current study around metacognitive experiences, as the participants did not report on this component. Given the importance that Israeli teachers reported and their beliefs about metacognitive experiences being the most practical component of metacognition, further PD surrounding metacognitive experiences should be prioritized. The findings from the Ben-David and Orion (2013) study demonstrate that these teachers' views could change with PD programming.

In this study, participants' beliefs and actions were significantly related to years of teaching experience. Participants with more years of experience reported more positive beliefs and an increased tendency to implement activities related to metacognition. Many veteran participants (all interviewees and most veteran respondents) indicated that they engaged regularly in self-directed learning about integrating new activities. This tendency to seek additional resources outside of the classroom might suggest a reason as to why veteran teachers tended to report integrating metacognition more extensively than early teachers. In terms of having more positive beliefs about metacognition, these teachers might simply have more experience with teaching and working to promote independent learning. Braund and Soleas (forthcoming) examined differences across preservice and in-service teachers regarding their beliefs about metacognition and integration. Their findings suggest that in-service teachers (n=45) have more concrete and practical knowledge of metacognition and are also better able to integrate metacognition. Preservice teachers (n=43) lacked conceptual understandings of metacognition and generally were unable to provide specific and concrete examples of integrating metacognition. Although the Braund and Soleas study was conducted with preservice and in-service teachers, their findings align with the findings from this study, suggesting that having more experience in the classroom may help teachers to integrate metacognition.

Gender was not a factor that significantly affected participants' beliefs or actions, perhaps as a result of the small sample size for males and consequent reduced statistical power. These results may also indicate that gender is not a factor that affects Ontario elementary teachers' beliefs about metacognition, nor does it impact their actions. A study conducted by Mai (2015) in Malaysia found that gender did not significantly affect primary science teachers' self-perceptions about metacognition.

As with previous studies (Pajares 1992; Woolfolk Hoy, Davis and Pape 2006), this study found that teachers' beliefs and actions were interconnected. This suggests that teachers' beliefs and knowledge inform their teaching. However, there have been instances where teachers' reported practices were incongruent with their observed classroom practices. Spruce and Bol (2015) found that American teachers had positive beliefs about self-regulated learning and associated metacognitive practices at the elementary and middle school levels. Yet, there were incongruences between teachers' reported practices and their actual practices within classrooms; teachers did not necessarily implement all of the reported practices. As a follow-up, a next step for this study would be to observe teachers to see if their reported actions are reflected in their classrooms. Similar to the findings from Spruce and Bol (2015), the participants in the current study had positive beliefs about metacognition and self-regulated learning components. Since participants from the current study held positive beliefs about metacognition, they may be open to learning more about the concept and how they could integrate it further.

Traditionally, researchers have examined metacognition in secondary and postsecondary students. Zohar and Barzilai (2013) identified this restriction to older students as a major limitation in the field, calling for more research on the elementary population, especially primary students. The age at which children are developmentally capable of thinking metacognitively has been debated for years (Schneider 2008; Whitebread et al 2010; Veenman, Van Hout-Wolters and Afflerbach 2006). There has been conflicting evidence in the field, with some studies finding that students begin to demonstrate metacognitive processes in late elementary years, while other studies have provided evidence of metacognitive processes in primary grades.

Participants' perspectives on metacognition generally aligned with research demonstrating that young children are cognitively capable of engaging in metacognition (Bronson 2000; Whitebread, Coltman, Jameson and Lander 2009). The majority of participants from the current study felt that children in kindergarten through Grade 3 could think about their thinking and learning. Some participants mentioned developmental limitations when indicating that they felt elementary students were generally capable of engaging in

metacognitive thinking. They acknowledged that older students (such as those in junior grades) are likely more capable of deeper metacognition and greater independence than primary students. Also, participants did report that students had a range of cognitive abilities and that metacognitive thinking would be different among students, suggesting the need to conceptualize metacognition on a continuum. Interestingly, concerns in the current study about developing students' metacognition were focused on developmental limitations rather than on ability levels, as found in Zohar, Degani and Vaaknin's (2001) study, in which only 20 per cent of their teachers felt that both low-ability and high-ability students could engage in higher-order thinking. The findings from the current study may indicate a shift towards believing that all students are capable of thinking metacognitively but may require different supports, dependent upon their cognitive development and ability levels.

Instances of young children monitoring and controlling their learning while playing in primary classrooms have been described (Whitebread, Coltman Jameson and Lander 2009). Specifically, children as young as three are capable of displaying early metacognitive behaviours such as planning their learning and reflecting on their learning (Whitebread et al 2005). Despite the presence of early monitoring and control skills in young children (ages three to five), explicit instruction is required to develop these skills further, since they are not fully developed in the absence of practice and guided instruction (Lockl and Schneider 2006; Schneider 2008). These findings align with the practices reported by teachers from the current study, who consistently reiterated the need for explicit instruction to develop students' metacognition. Further, participants from the current study detailed how they would point out when students were using metacognitive strategies and model how students could use the strategies, aligning with findings from Lockl and Schneider (2006) and Schneider (2008).

While metacognitive thinking tends to become more explicit with older students, participants from the current study struggled with determining the extent to which their students were being metacognitive, especially when the students were not explicit about their thinking. This has been a longstanding issue in the literature as researchers struggle with how metacognition can be measured (Georghiades 2004), especially in the primary grades, with new tools under development (Whitebread et al 2009). Through the use of developmentally appropriate measurement tools, teachers can recognize primary students' potential as metacognitive learners.

The activities and prompting used to encourage students' metacognitive thinking must be developmentally appropriate. Schraw and Moshman (1995) reported early cognitive use in four-year-olds who were capable of using theories to regulate and think about their learning, while six-year-olds demonstrated accurate reflective thinking, a key component of metacognition.

Results from the current study indicated that teachers believed that young children in primary grades can think metacognitively, which is promising given Schraw and Moshman's (1995) findings that indeed students as young as four years of age have the cognitive capacity to think about their thinking. The findings from the current study suggested that metacognition be considered on a continuum and that, generally, participants believed that students were capable of thinking metacognitively, but it looks different among students. Therefore, we need to be mindful of a range within classrooms as teachers work to integrate metacognition. Further, we need to ensure that the way students' thinking is made visible is appropriate given their current developmental level. Therefore, this longstanding debate of whether or not young students can think metacognitively must move forward with current literature showing metacognitive abilities in young children. Future research should consider how we can support the development of metacognition in young children through developmentally appropriate activities. Teachers may also benefit from additional PD in how strategies can be modified according to developmental levels to help accommodate for the continuum conceptualization. There is also a need for teachers to understand all three components of metacognition, given that metacognitive experiences was not mentioned or discussed in the current study despite its demonstrated importance in previous literature (Ben-David and Orion 2013; Efklides 2006).

Limitations

The reliability analyses suggested that the scale consisting of Likert-type items used to measure teachers' beliefs and actions was fairly reliable as a result of being above 0.8 (Field 2013). However, the belief scale was not nearly as reliable as the action scale. Adding more belief items and rewording some of the items with low reliability might increase the lower reliability for the belief scale above its current 0.720. The grouping for early and veteran teachers was rather close, with early experience ranging from 0 to 5 years and veteran starting with 6 or more years. If this study is replicated, the researcher would recommend an additional grouping of moderately experienced teachers, with experience ranging from 6 to 10 years. This study also primarily focused upon metacognitive knowledge and metacognitive regulation components, with fewer questions about metacognitive experiences. Future research should continue to explore metacognitive experiences. The instrument used also had limitations because it was a self-report measure, but it was followed with interviews to strengthen the mixed-methods study.

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Applying Utility-Value Writing Prompts to Science Education

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Abstract

Helping junior high and high school students remain interested in science increases the chance that they will pursue careers in science. However, there are many different ways to trigger or sustain interest. Utility-value writing assignments represent a type of motivation intervention that has consistently demonstrated a positive effect on students' interest and performance in science. In this paper, we describe expectancy-value theory as the framework giving rise to utility-value interventions and review evidence of the effectiveness of the intervention. Then we provide educators with concrete steps for writing and scoring utility-value writing assignments.

Applying Utility-Value Writing Prompts to Science Education

Often the top-listed careers in North America involve science in some capacity (Canadian Business 2017; U.S. News 2019). To attain these types of careers, individuals require advanced education in the field of science. The likelihood of any student pursuing advanced education related to science is dependent on, at a minimum, maintaining interest in science content (Renninger, Nieswandt and Hidi 2015). Thus, it seems that more than ever, many parents, teachers, researchers and government alike are committed to initiating, sustaining and hopefully increasing interest in science (Maltese, Melki and Wiebke 2014). In Alberta, this commitment is evident within the Program of Studies for Science Education (Alberta Education 2003), which explicitly states one of its five goals as "to enable students, of varying aptitudes and interests, to develop a knowledge of the wide spectrum of careers related to science, technology and the environment."

Despite this external focus on the importance of science, students' interest in science, particularly for girls, declines from junior high school through Grade 12 (VanLeuvan 2004). In a large-scale retrospective study of college students' original interest in science, Maltese, Melki and Wiebke (2014) showed that the influence of teachers in sparking students' interest in science is highest in Grades 6 through 12. Despite this potential influence, it can be difficult to know which activities or assignments can build interest in students. As an alternative to refining the structure of an activity, motivation theory suggests that interest can be influenced by changing students' perceptions of the learning. The field of achievement motivation is replete with empirical evidence documenting how motivation principles (eg, Elliot, Dweck and Yeager 2017), designs (eg, Linnenbrink-Garcia, Patall and Pekrun 2016) and interventions (eg, Lazowski and Hulleman 2016) can help increase students' interest. One of the most effective and simple of these interventions extends from the expectancy-value theory of motivation (Eccles and Wigfield 2002). The purpose of this nonempirical paper is to provide an overview of the expectancy-value theory of motivation (Eccles and Wigfield 2002), review utility-value writing interventions as an empirically-supported means of enhancing interest in science (Hulleman and Harackiewicz 2009) and articulate steps that science educators can use to design their own utility-value writing assignments.

Expectancy-Value Theory of Motivation

Expectancy-value theory has a long tradition in science education. In fact, one of the original expectancy-value models (Eccles et al 1983) was proposed with the explicit purpose of explaining why, despite similar performance levels in early grades, girls were less likely to pursue higher-level math courses than boys. According to contemporary expectancy-value theory (Eccles and Wigfield 2002), academic choices including whether or not to persist are largely determined by two subjective beliefs that underpin student motivation. The first belief is related to a student's expectancy that he or she will be successful in the task. Fundamentally, it is the student's response to the question: Can I do this task? When the answer is yes, the student has met a minimum threshold to move into action. The second belief is related to the *value* or the overall importance of the task. This belief arises from a student's response to the question: Do I want to do this task? An affirmative response, again, energizes the learner towards investing energy in the task.

Value comes in at least three forms. First, *intrinsic value* refers to wanting to do a task simply because it is enjoyable. Second, *utility value* refers to choosing to undertake a task because it will be useful in the short or long term. Third, *attainment value* applies to students who undertake tasks because it reaffirms their identity and thus meets a personal need. In a multiplicative fashion, when expectancies and values are both high, intrinsic motivation tends to be high as evidenced by sustained interest, persistence and performance (Wigfield, Tonks and Klauda 2009).

In opposition to value, expectancy-value researchers acknowledge that students must balance the cost of each pursuit (Flake et al 2015). Defined as "what an individual has to give up to do a task, as well as the anticipated effort one will need to put into task completion," (Eccles 2005, 113) cost has been touted as the "forgotten component of expectancy value theory" (Flake et al 2015, 232). Just as value had three types, so too was cost hypothesized to take its toll in three ways. First, students may perceive the cost of effort needed to be successful as not worth it. Second, students may experience a reduction in motivation if they suffered a loss of valued alternatives by investing effort in one activity at the expense of others. And finally, students balance their chances for success against the psychological cost of failure. Cost, both in specific dimensions and generally, is negatively correlated with grades, interest and overall motivation (Flake et al 2015), and positively predictive of an intention to leave STEM majors in college (Perez, Cromley and Kaplan 2014).

ASEJ, Volume 46, Number 1, September 2019

Hulleman et al (2016) suggest that "as teachers encounter motivation problems with their students, deciding if the problem is an expectancy, a value, or a cost problem is a critical first step in determining how to intervene" (p 258). Although this is true, we focus the remainder of this paper on value in science because the content of utility-value interventions can be applied by teachers to the creation of science writing assignments.

Utility-Value Intervention Evidence in Science Education

Building on the theoretical foundation of expectancyvalue theory, and particularly utility-value, Hulleman and Harackiewicz (2009) argued that "[m]aking science courses personally relevant and meaningful may engage students in the learning process, enable them to identify with future science careers, foster the development of interest, and promote science-related academic choices (eg, course enrollment and pursuit of advanced degrees) and career paths" (p 1411). Over the past 10 years, a large body of evidence has accumulated showing that utilityvalue interventions indeed enhance students' interest in science. For example, Grade 9 science students who received a semester-long motivational intervention in which they were encouraged to draw connections between the science content and their lives reported higher interest and achieved higher scores than students in a control group (Hulleman and Harackiewicz 2009). Moreover, these results are strongest for students with low expectations for success, who may be in the most need of support. Since this foundational evidence, utility-value writing interventions have been applied with similar success in high school and college biology, mathematics and psychology classrooms, resulting an increase of up to 0.80 in GPA on a four-point scale, compared to control groups (eg, Canning and Harackiewicz 2015; Gaspard et al 2015; Harackiewicz et al 2016; Hulleman et al 2010; Hulleman et al 2016; Hulleman et al 2017).

Why They Work

Researchers stand firm that psychosocial interventions are not magic (Yeager and Walton 2011). They work because researchers understand the psychological processes underpinning the intervention. For utility-value interventions, that process is utility value precisely. In other words, a utility-value writing assignment is likely to affect outcomes because it increases the student's utility value for the content. Although it may also affect related constructs such as expectancy, self-efficacy or effort, these beliefs are not specifically targeted by utility-value interventions and thus a desire to increase these sorts of beliefs may not be met through utility-value writing assignments.

What Students Write

Perhaps because of the precision and rich theoretical backing, at the outset, utility-value researchers focused on the impact of the intervention on outcomes such as interest and persistence without considering students' actual responses. Remedying this, in a study with Grade 5 and Grade 6 students, Akcaoglu et al (2018) examined the types and quality of student responses generated by a utility-value writing intervention. The researchers created a "real-life connections rubric" (p 72) and undertook a content analysis of the student responses. They concluded that students in the intervention group produced essays that included more utility-value statements (ie, links to life and applications) than the control group. This type of writing was characterized by substantially more usage of personal pronouns, along with words such as family, friend and insight. Klebanov et al (2017) also provided a linguistic analysis of written responses with the hope that artificial intelligence (AI) may play a role in scaling up utility-value interventions.

Steps for Creating and Scoring a Utility-Value Writing Assignment

Despite this compelling evidence in favour of utilityvalue interventions, there has been little attempt to make the principles of the intervention available to science teachers. If teachers were to access the original empirical papers, they would find neither the actual intervention materials nor clear guidance on how to create or score utility-value writing assignments separate from research purposes. The failure to translate intervention materials into materials accessible to teachers represents a shortcoming of the field and one that appears to not adequately bridge theory, evidence and practice.

At our request, the researchers provided us with the exact utility-value intervention materials used but not published in Harackiewicz et al 2016. We reviewed these materials and concluded that there are two primary characteristics of a self-generated utility-value intervention that can be translated into directions in formulating a utility-value writing assignment. First, students must

formulate their own question to be answered related to the content covered. Although the content area can be either broad (eg, Grade 9, Unit A, Biological Diversity) or specific (eg, Grade 9, Unit A, key concept: inheritance), it is crucial that students generate their own question. Evidence suggests that self-generated questions and utility-value statements are more effective than statements directly provided to students by someone else (Canning and Harackiewicz 2015), particularly for lowachieving students (Harackiewicz et al 2014). Second, students must make explicit connections between the course content and its value rather than just summarize the content. More precisely, students have been asked to describe the value for themselves personally, for another individual or for society as a whole (Klebanov et al 2017). Instructions to encourage students to make these sorts of value connections, by audience, are described in Figure 1. We hope that this template will allow teachers to extend these two guiding principles to their own writing assignments.

In addition to extracting two steps to creating utility-value writing assignments, we have adapted the rubric designed by Akcaoglu and colleagues (2018) and included it in Figure 1. We direct the reader to Akcaoglu et al (2018) for specific examples related to scoring. However, generally, utility-value writing assignments do not differ from traditional writing assignments in terms of requiring accurate content to answer the question or upholding standards related to writing style, format, spelling and expression, although the latter does not have to be scored. In scoring utilityvalue writing assignments, a minimum of three separate components tend to be evaluated:

- 1. The formulation and inclusion of a question to be answered. This question sets the tone for the assignment and thus should be explicitly stated in the title or in the first paragraph of the assignment and thus graded.
- 2. Accuracy of the content presented to answer the question. This should be scored by the same standards as any essay or short-answer question. The addition of a utility-value component does not change the importance of accurate content.
- 3. The depth of utility-value connections. Students produce a wide range of relevance statements, some of which are very convincing and personal and others that are more vague and general. Stronger personal connections to the content should be scored more highly than weaker or generic scoring.

Figure 1.

Explanatory Steps and Instructions for Creating a Utility-Value Writing Assignment

	Standard Assignment	Utility-Value for Self	Utility-Value for Other	Utility-Value for Society	
Rationale	None provided	This assignment is designed to help you understand major concepts covered and focus on the relevance of one particular topic for your own life.	This assignment is designed to help you understand major concepts covered and focus on the relevance of one particular topic for someone in your life.	This assignment is designed to help you understand major concepts covered and focus on the relevance of one particular topic for society.	
Instructions	Please answer the following question based on what we have learned in the unit.	1. Select a concept that was covered in the unit and write a question you would like to answer. Here is a sample question: What is the difference between heritable and nonher- itable characteristics?			
	You need to organize your response logi- cally. Be sure to summarize what you have learned in about one to two pages.	2. After writing your ques- tion, use the relevant infor- mation to write a one- to two-page response. You must answer the question correctly based on the con- tent we learned and discuss its personal relevance to your own life. Include ex- amples about how the infor- mation applies to you personally.	2. After writing your ques- tion, use the relevant infor- mation to write a one- to two-page letter to a family member or friend who could benefit from this informa- tion. You must answer the question correctly based on the content we learned and discuss its personal rel- evance to the other person. Include examples of how this information applies to them.	2. After writing your ques- tion, use the relevant infor- mation to write a one- to two-page answer. You must answer the question cor- rectly based on the content we learned and discuss its relevance to society in gen- eral. Include examples about how the information applies to people living in our society.	
Sample Question	What is the differ- ence between heri- table and nonher- itable characteristics?		Why does my sister have blue eyes if both her parents have brown eyes?	Why were there so few children with blue eyes in my elementary school?	
Possible Scoring for Response	Level 0—just a summary Level 1—application or example without personalization; eg, people have different-coloured eyes Level 2—specific application to appropriate audience but mechanism is not fully explained; increased use of pro- nouns; eg, I have blue eyes but my mom has brown Level 3—specific application to appropriate audience and mechanism is explained; lots of pronouns and reasoning language such as "because"; eg, I have blue eyes, my mom has brown, but my child may have brown because				

Examples

We have not used utility-value writing assignments with teachers in Alberta. However, based on the existing literature and the samples that were submitted by the researchers, we can envision what such assignments might look like. Imagine having completed a unit on biological diversity (Grade 9, Unit A). A teacher might ask students to generate questions related to sex-linked heritable traits. In response to the self-generated question, "Will I go bald?" one student may explain his own chances of ending up bald based on the other people in his family, concluding that "I will rest easier knowing that it isn't a guarantee that I'll be bald." Another student could pose the question "Will my baby have blue eyes?" and describe the conditions under which her child might end up with blue eyes, even though she has brown eyes. Both of these examples would be considered high in utility-value content and should receive high scores on the utility-value portion of the scoring. Scores should be reduced as the explanations become more as generic, including statements such as "Some people go bald" or "The colour of a child's eyes is related to the colour of parents' eyes."

An Important Caveat

Teachers will have to determine the effectiveness of this type of assignment for their students on their own and in each case. The purpose of classroom assessment is to determine the extent to which learner outcomes have been reached, and thus enhancing utility value is obviously a secondary consideration for teachers and should not interfere with students' abilities to show what they have learned.

Conclusion

Although the empirical data supporting the effectiveness of utility-value interventions is compelling, the translation of research design into materials for teachers is lacking. Our purpose was to determine the key components of utility-value writing prompts so that they may be used by teachers. By extracting key steps based on the experimental materials (Harackiewicz et al 2016), we hope science educators will consider adapting some assessments to be more congruent with a utility-value perspective, thereby increasing the chances that students will remain (or become more) interested in science.

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Imagining Possible Futures with Science Fiction: *Doctor Who* and the Classroom

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Abstract

Science fiction provides opportunities to explore future scenarios and critique contemporary society. This paper engages with an episode of *Doctor Who* to connect future studies to praxis within the context of biology and ecology by envisaging possible, probable and preferable sociotechnological futures and engaging students in the development of their sense of agency when imagining their preferable futures. The episode "Gridlock" allows us to explore a future in which science and technology in society have led to lethal drug use and dangerous air quality, and yet leaves us hopeful that a utopian society is possible.

Science fiction is the most important literature in the history of the world, because it's the history of ideas, the history of our civilization birthing itself ... Science fiction is central to everything we've ever done.

—Ray Bradbury

Introduction

Our relationship with the past and future is complex. Harsh realities or predictions can be difficult to bear, and we live in a time ripe with fears—for example, toxic air quality and drug use. Students might recognize these (and other) bleak possibilities, and yet wish for a more preferred future (Eckersley 1999; Hicks 2004; Hutchinson 1996). How might teachers address serious environmental and social issues without dampening students' hopes for the future? The intention of this paper is to use an episode of the science fiction television series *Doctor Who* to illustrate how to connect future studies to praxis within the context of biology and ecology: "From a futuresoriented peace study perspective, the challenge for teachers is ... to encourage critical and imaginative readings in which teachers and students are colearners in negotiating preferable futures" (Hutchinson 1996, 46).

Encouraging critical and imaginative thinking is key to the process of envisaging the future, but teachers need strategies (den Heyer 2017). The use of science fiction could be one such strategy. Key to the process of envisioning the future is imagination, which might be stirred through such a use, because incorporating imagination into teaching strategies encourages critical thinking (Noone and Cartwright 2005/6). Fiction can tap into students' imagination to bridge gaps in space and time. Historical fiction ties the past to the present (den Heyer and Fidyk 2007), and science fiction can be a bridge to the future. As Hutchinson (1996) noted, when asked what the future likely holds for us, students tended to respond with a bleak view for the future; however, when asked specifically what their preferable future might hold, the responses were generally filled with hope. Examining scenarios (that is, narratives rather than a definitive prediction) helps students with their reasoning skills, and specifically helps them delineate between possible and preferred futures (den Heyer 2017; Staley 2002). Spending time with students talking about the variety of possibilities for the future affords them the opportunity to examine what they might like to see happen, and science fiction can help them with that task.

Surface-Level, Interpretive and Critical Knowledge

Engaging students in analysis of the future requires various types of knowledge: surface-level, interpretive and critical (Rawnsley 2000). Surface-level knowledge is mainly descriptive, based on observations, and is the first step to engaging in discussions of the future. In science classrooms, it is insufficient to rely solely on surface-level knowledge, because it lacks the recognition that society is integrally connected to epistemology and ontology. Interpretive knowledge moves beyond the unilateral acceptance of one world view, recognizing "multiple interpretations of reality," and thus student responses may vary according to their own "cultural interpretations of the problem" (Rawnsley 2000, 47). Unfortunately, this type of knowledge may not free the individual from their one indoctrinated, epistemologically approved notion of culture and meaning. However, the inclusion of critical knowledge can facilitate a contemplative examination of underlying personal and societal assumptions and values. Critical knowledge urges students to examine value-based power relationships and how this ties to the future. Looking at different cultural perspectives requires students to both examine and deconstruct while analyzing future possibilities, an aspect of future studies not possible if the students use only surface and interpretive knowledge (Rawnsley 2000).

Possible, Probable, and Preferable Futures

In order to develop surface-level, interpretive and, especially, critical knowledge in the context of contemporary controversies and their future implications with students, first we need to establish a framework for discussion: the possible, the probable and the preferable.

Possible futures are all the scenarios that might happen, regardless of how likely they are. In science fiction, a "many worlds" interpretation filled with almost limitless possibility is common. Such an interpretation is based on the work of the physicist Hugh Everett in 1957, although many others have worked in this field. Essentially, the concept of many worlds entails that actions (and inaction) produce multiple possible outcomes, each of these possibilities creating a new world.

For example, were there a scenario in which you were in danger of death, two worlds would be created—one in which you lived and one in which you did not. Regardless of belief in the many-world interpretation of time, such wonderings give students a sense that the future is not already colonized by the present, although the current trajectory is recognized. Whether we have one world or many, we feel that it is important for students to see that there are a variety of possibilities for the future—there is not one prescribed future.

Probable futures are connected to current society. There must be a logical progression from now to then and, as such, students would find "connections between the present and envisaged futures" (Rawnsley 2000, 40). Certain scenarios would be more likely, given the state of the current society. Students often find these probabilities to be prescribed by those perceived to be in power, and these futures are very bleak; Hutchinson (1996) noted in his study of Australian youth that a great majority predict ecology-related problems, with less than 10 per cent believing that any progress will be made over the next five years (pp 78– 79). Responses included such statements as

I saw a dry and dead environment ... The beaches and the air were destroyed by pollution and people were dying fast ... There was guns and fighting going on all over the world. Most people were poverty stricken and were forced to live on the streets ... The world to me wouldn't be worth living in. (Hutchinson 1996, 79)

Another student also predicted that "pure water and oxygen [would be] for sale" (Hutchinson 1996, 79) because they would be in such short supply.

In contrast with probable futures, Hutchinson's (1996) research revealed students' *preferable* futures to be filled with hope. Preferable futures require students to decide which of the possible futures they wish to happen. Unlike probable futures, preferable futures are less linked to present society, but rather tend to be linked to students' value systems. Young men tend to envisage a technological fix for our present social and ecological problems, whereas young women tend to tap into alternative knowledge traditions and imagine ways of living in harmony with our planet (Hutchinson 1996, 84–85). In other words, young men tended to see a technocratic fix while women used more "Earthcare" and "socially just-world" imaging (Hutchinson 1996, 85). Although Hutchinson's gendered analysis is

interesting, it is incomplete. For example, possible connections between violent play and pessimism about the future are not explored, and there is little guidance on how to avoid reinforcing stereotypical gendered preferences (Mansfield 2000, 105). Regardless of gender, students seem to desire a very positive future despite the fact that they see a more pessimistic probable future, and thus it is important to discuss the many possibilities that the future holds:

Images of the future in the Western World often hinge narrowly around scientific and technological developments, sometimes seen as beneficial but more often as dystopian. It is as if science and technology have a life of their own which the ordinary citizen feels she can neither understand nor control. In the face of such fears it is increasingly important to focus on people's images of preferred futures. If they can be elaborated and envisioned more then perhaps they can provide the basis for creating a more just and sustainable future (Hicks and Holden 1995, 51).

Science fiction, and *Doctor Who* as an exemplar, can help us navigate the complex waters of science, technology and society as our hopes and fears are placed on screen and serve as a stimulus for discussion.

Science Fiction, *Doctor Who* and Society

As Tulloch and Jenkins (2005) set out, popular culture genres like science fiction operate as modern myths and fables. They provide warnings and insight into topical issues and speak to very particular moments in time-for example, moving from the fear of nuclear disaster in the 1960s to the fear of ecological disaster present in the 21st century. Doctor Who first aired in 1963, and the original series ran until 1989; it was revived in 2005 and has continued since. Such longevity has made Doctor Who a quintessential work of science fiction in popular television-generations have followed the exploits of the time- and worldtravelling Doctor. Sydney Newman, the main figure behind the creation of Doctor Who, described science fiction as "a marvellous way-and a safe way, I might add-of saying nasty things about our own society" (quoted in Harrison 2013, pgph 5). Doctor Who has done exactly that over its fifty-year span, saying "nasty" things about society over the years, and yet the

Doctor's "politics and ethics ... have proved as malleable as its core cast" (Harrison 2013, pgph 5). However, this malleability does not detract from its effectiveness in engaging its audience with contemporary concerns of future ramifications. As a series, *Doctor Who* has been able to morph over time literally and figuratively—the protagonist (the Doctor) can regenerate, thus allowing different actors to play the character over time. Consequently, the Doctor retains his memories but his personality and interests vary over time, which undoubtedly reflect the episode writer and producer. For this reason, we have chosen to focus primarily on particular episodes rather than the series as a whole.

A unique feature of Doctor Who relative to other popular science fiction is the diversity of its perspectives on future challenges to morality and our sense of humanity. Over the course of fifty years of Doctor Who, the creative team has changed every few years. According to Harrison, this situation has created a dynamic, open-sourced opportunity to address a variety of issues with diverse messages and emphases. Some might critique seeming inconsistencies in the Doctor's actions; for example, Tom Baker's Doctor could not commit genocide of the Daleks, and yet Sylvester McCoy's Doctor used a planet-killing device against them (Harrison 2013). However, consistency is not a valid criterion for the effectiveness of the series to critique contemporary society. With both Tom Baker and Sylvester McCoy, audience members were faced with the issue of genocide and would either celebrate or condemn the Doctor's actions accordingly. Inconsistency entails merely that it is more effective to examine individual or sets of episodes rather than the whole series in relation to social critique and fears for the future.

Doctor Who provides timely critiques of both contemporary society and our fears for the future. For example, "The Mutants" (1972) examined racial separation and inequality on an alien planet, a strong critique not only of South Africa but also of right-wing attitudes in broader society, while some scripts in the 1980s clearly critiqued Margaret Thatcher (Harrison 2013). *Doctor Who*, like many other works of science fiction, is able to capture our hopes and fears for the future. Here, the show follows in the footsteps of H G Wells and Aldous Huxley in its ability to reveal future manifestations of present concerns. In the episode "The Daleks" (1963), Terry Nation creates an enemy who is dehumanized not by a lack of rationality, a common feature of popular conceptions of evil, but by an excess of rationality. The Daleks are considered to be very intelligent, advanced and civilized (Bunce 2010, 341); however, they represent a "nightmare future" because they evolved to lack basic emotions, the most important being empathy (Bunce 2010, 349). They once had empathy but they have now lost this sense, just as humanity today might lose itself as emotions (including empathy) dwindle (Bunce 2010, 342). The Daleks warn us about the potential for evil of our contemporary society. Western society continues to be dominated by the ideas of the Enlightenment, and rationality rests at the heart of this world view, yet an excess of rationality at the expense of empathy and community is a very real problem that science fiction has been exploring, most notably Aldous Huxley's Brave New World (1932) (Bunce 2010, 341).

Science fiction as a genre is ripe with possibilities for its viewers and creators. For example, the European science fiction author Mack Meijers enhances his understanding of the present by observing people and current technology, which then inspires him "to map out potential future scenarios" (Brown 2013, 959). Writers like Meijers and their audiences use science fiction as a means to imagine a world beyond the present; for some it is escapism, and for others it is a way to address contemporary fears. The stories can be of love, horror, idealism or warnings. Star Trek, by Gene Rodenberry, illustrates an element of escapism as it showed the world as an idealistic place where all humans were equal and our differences negated, while Doctor Who writers such as Russell T Davies have taken another approach. Davies's stories are filled with both warnings and hope that stem from our very real fears of today manifested in worlds different from our own, and such stories are ripe with possibilities for exploration in the classroom.

"Gridlock"

Russell T Davies's exploration of the futuristic New New York, in the episode "Gridlock," allows viewers to see some of their fears of ecological collapse come to fruition. Using this episode with youths in a biology classroom would provide an opportunity to engage students to imagine what they see as possibilities for the future, considering such challenges as drug use and toxic air quality. "Gridlock" builds on a rich tradition within the *Doctor Who* series to critique society and address our fears for the future.

"Gridlock" is the last episode of a trilogy spanning the first three seasons of the rebooted Doctor Who series: "The End of the World" (season 1, 2005), "New Earth" (season 2, 2006) and "Gridlock" (season 3, 2007). "Gridlock" is set in 5,000,000,053 in New New York on New Earth. In the initial scenes of this episode, two individuals in a vehicle are attacked; they call the police for help but receive no reply. We are then taken to the Time and Relative Dimension in Space (TARDIS) when the tenth Doctor and his new companion, Martha, arrive in an alley in the under-city or, as Martha proclaims, "the slums." While wandering the under-city, Martha and the Doctor encounter vendors selling "mood enhancers," which are patches attached to the body that enable the recipient to forget, sleep or whatever the mood suggests. At this point, Martha is kidnapped by two carjackers, Milo and Cheen. The Doctor chases after Martha and finds his way to the motorway but is soon overcome by the exhaust fumes and unable to breathe. At this point, Thomas Kincade Brannigan and his wife pull him into their van. The motorway comprises a gridlock of millions of cars and life-threatening levels of smog. The Doctor cannot believe that people have just sat in their vehicles when the authorities have obviously abandoned them. Meanwhile, Martha discovers that the reason for her kidnapping was to enable Milo and Cheen to enter the fast lane (three passengers are required) and hopefully find their happily ever after faster, because the fast lane allows them to bypass the gridlock. When Martha, Milo and Cheen enter the fast lane, they are warned to leave but are unable to do so. They are attacked by the Macra, large crab-like aliens who live on exhaust fumes and have devolved into monsters. Meanwhile, the Doctor has travelled from van to van pretending to be the motorway patrol and he is above the fast lane deciding what to do. At this time, the Novice enters the van. The Novice had met the Doctor in "New Earth," and when she discovered that he was in New New York, she followed him. She transports him to the Senate, and the Doctor is elated because he thinks that now he is in the over-city he will be able to get help for Martha. However, as he looks around the Senate, he notices an abundance of human remains. The Novice informs him that 23 years ago, a new mood, "Bliss," became all the rage, but it mutated into an airborne virus that killed everyone in the world in seven minutes. The last act of the Senate

was to save the human race from the virus by closing the under-city from the over-city, trapping everyone below. Although the virus dissipated, the Senate had placed a quarantine around the planet that prevented anyone from landing for 100 years. Thus, the under-city consists of a motorway of millions of people who are kept in constant traffic, driving to a destination that they assume will mean a better life. They are completely unaware that the society above no longer exists, the government has collapsed, the people have died and the only reason the motorway is still functioning is due to the Face of Boe. The Doctor is able to fix the system, enabling the motorway to be opened; however, the Face of Boe must give the last of his life for this to happen. The Doctor sends a broadcast to all drivers telling them to drive up and escape the motorway. The characters look up in awe as they see the sun for the first time in decades.

Using "Gridlock" in Classrooms

Science has its own history and is influenced by society both socially and culturally (Chahal 2011; Lederman and Lederman 2004), and Doctor Who is able to illustrate many aspects of science in the context of society. The critique of ecological degradation and drug use in "Gridlock" provides an opportunity to engage students in discussions regarding contemporary concerns that affect our hopes and fears for the future. Issues of science, technology and society are woven throughout "Gridlock," providing educators with a resource for examining future scenarios with students. As addressed by Tullock and Jenkins (2005), Doctor Who is an encapsulation of modernity, and modernity is best signified through science and technology. Students can be engaged in alternative futures by asking them what they believe is probable or prescribed, what else they can imagine, and which scenario they hope will happen (Rawnsley 2000). Doctor Who provides students with a platform from which to build and envisage future scenarios using their creativity and imagination. For example, what other possible futures were there, besides what happened in the episode? Which of those futures would the students prefer? According to Rawnsley (2000), the knowledge gained through "media is often divorced from social action" (p 44), but science fiction can allow one to move beyond this surface knowledge. In particular, "Gridlock" provides the opportunity to use interpretive and critical

knowledge as the world that is being discussed is directly linked to tacit knowledge of Earth.

In "Gridlock," science and technology enabled the creation of the mood enhancers that led to a mutation and eventual viral outbreak that caused the collapse of the over-city. This element of the episode mirrors contemporary concerns about the short-term and long-term dangers of drug use, such as injury to key organs and body systems and even death (for example, Gate-way Foundation nd). Curriculum exists regarding drugs and addiction, such as the National Institutes of Health (NIH) Curriculum Supplement Series for Grades 9–12, and explorations of "Gridlock" could be used to support the formal curriculum by engaging students in an audiovisual medium that can serve as a talking point about related issues.

For example, the episode could be used in a science class to initiate discussion about the dangers of drug use, both prescription and illegal, as well as the interplay of science, technology and society. A mood-drug like "Bliss" could be compared with antidepressants as well as illegal drugs like Ecstasy (MDMA). Both have wellknown side effects. Ecstasy can impair cognitive functioning (Golding et al 2007) and, in some cases, can lead to death; a 2002 study showed that approximately 11 per cent of high school seniors have experimented with the drug, a figure that had doubled since 1997, along with more than double the emergency room visits related to ecstasy (Rivas-Vazquez and Delgado 2002). Later studies confirmed neurotoxicity as well as attention and memory impairments in moderate to high Ecstasy users (Adamaszek et al 2010). Antidepressants can cause common symptoms such as nausea, fatigue, insomnia and anxiety, as well as less common but worrisome symptoms such as suicidal thoughts (Cooper et al 2014). Despite the benefits of antidepressants and the attraction of Ecstasy (to some), the side effects lend themselves to a debate over whether or not the benefits are worth the potential harm. Using the examples above, the mood enhancer "Bliss" from Doctor Who provides a means to discuss such fears about these drugs (or others) with students. The science fiction example is extreme, yet might provide a safe space to talk about drugs because it is fictional. Having a debate about antidepressants or Ecstasy might be a trigger for students who either are taking them or know someone who is. In this sense, underlying anxieties can be expressed in a less threatening way. It should be noted, however, that tying this discussion back to antidepressants or Ecstasy afterward might pose a similar psychological threat, so it is recommended that teachers undertake these connections only after the class has had time to digest the fictional material.

This sort of interplay between biological concerns and science fiction is not new. For example, Joan Slonczewski, a professor of microbiology and science fiction writer, was inspired by the gene-integration capacity of human immunodeficiency virus (HIV) to write about positive gene therapy using the virus. This exploration of a possible future for HIV has now been mirrored by reality; HIV is now touted as a vector for gene therapy to help cancer patients and others (Brown 2013, 960). Science fiction as a representation of contemporary hopes and fears as well as a source of inspiration makes episodes like "Gridlock" an interesting focal point for a class discussion.

The fact that the residents of the under-city are trapped in vehicles on a motorway and the broken air vents are creating toxic air pollution illustrates present anxiety and warnings about air quality in large cities. A Google search on September 8, 2018, using the search term toxic air quality yielded more than 164,000,000 results. News articles included such titles as "China's Toxic Air Pollution Resembles Nuclear Winter, Say Scientists" (Kalman 2014) and the interactive map of the United States, "Poisoned Places: Air Pollution in Your Town" (Hsu 2011). Also included are articles about the US Environmental Protection Agency's recent, and controversial, lifting of limits on toxic pollution (for example, Irfan 2018). When addressing these issues, teachers may be faced with students who seem either apathetic or anxious about air quality, so the episode "Gridlock" might engage students with a fresh approach to introducing the topic. If, however, students are either apathetic or anxious because they feel no sense of agency to effect change, the hopeful message of the episode might serve as inspiration for them.

Despite the dark, dystopian aspects of the episode, the scene of the motorway passengers driving to the over-city provides a strong sense of hope. The motorists from the under-city had maintained their sense of community and empathy, and when the Doctor literally opens the sky and allows the sunlight in, the future is not yet defined or predetermined. The government can be re-created, the air is clean and the future bright. The development of the episode from dystopia into potential utopia provides a useful platform to engage youth in contemplating the future by linking possible, probable/ prescribed and preferable futures through science

fiction. Using the obvious issues present in the undercity as a probable future, students could begin to envisage how to change current societal trends to prevent that future. This visualization requires interpretive and critical knowledge, as they must see their society's role in the probable outcome and then take a critical approach to be able to imagine how to change the outcome. For example, students could be asked how, using scientific and technological creativity, one can prevent a future society in which breathable air is nonexistent. Can science and technology lead to the collapse of our society or can they help create a better one? The questions are endless, yet the key is that all of the questions stem directly from the episode and require the students to go beyond their surface-level knowledge when discussing possible future outcomes.

Conclusion

At its core, science fiction is often a narrative rich with commentary and critique of contemporary society. Doctor Who has been an exemplar of such critique from its inception to the present. As educators, it is essential that we find and use platforms that enable us to guide pupils to become critical thinkers when envisioning not only the society that surrounds them now, but also the societies that they will help form. Envisioning the future can be frightening; however, when teachers structure lessons so that students engage in possible and preferable futures rather than simply probable/ prescribed futures, contemplation of the future can be an exercise that encourages agency and hope (Hutchinson 1996). Many Doctor Who episodes depict changes to both technology and ecology as equally capable of creating a utopian society out of a dystopian situation. Discussions of possible, probable and preferable futures can subvert what Hutchinson calls the "colonization of the future" because attention is paid to the intersections of present beliefs, both personally and in a broader sense, and the animating desire for hope and actions for improvements (Hutchinson 1996, 36). The discussion of preferable futures can then lead to proactive discussions about what needs to happen for such a future to become reality, ideally shaking students from a sense of powerlessness to one of agency. If as a society we desire peace and sustainability, we must exercise foresight and listen to youth about their visions for the future in responsible and empowering ways (Eckersley 1997). The episode "Gridlock" is one *Doctor Who* episode of many that could be used to engage students in critically discussing the possibilities for the future. Students, like the Doctor, are able to "travel through space and time" as they begin their explorations of the future.

When I was a child, my favourite story was about a man who lived forever but whose eyes were heavy with the weight of all he had seen. A man who fell from the stars.

—Eleventh Doctor (Matt Smith)

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Student Talk and Learning in Science

Jeff Turner

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Learning is an active process of making meaning by linking prior knowledge and experiences with new information taken in by the learner Teachers are searching constantly for ways to engage students in a more active learning process, trying to provide the best possible learning opportunities for each student. Researchers have shown that students' learning is enhanced when talk plays a key role. Talk enables us to discover what we know or mean, make relationships, organize our thinking, make discoveries, trade ideas and arrange our world. Talk allows us to link new knowledge with established understandings, thus making the new knowledge more personal, more secure. When we explore ideas through talk with others, we formulate and articulate our own understanding, frequently discovering that other people see and interpret the same ideas from a different viewpoint.

When everyday talk is compared with the generally perceived school use of talk, this common talk is viewed as a nuisance rather than as a value. Typically, students' talk is limited in quantity and purpose by a controlling model of teaching. Interaction during class time remains largely restricted to a classic triad pattern of (1) teacher initiates, (2) students respond and (3) teacher evaluates. The power balance is weighted too heavily toward the teacher's knowledge and not in favour of what students actually understand.

This research project considered the role that talk plays in learning in the science classroom. The research pulled together the theoretical knowledge and current research. A review of the few studies that had explored how children's talk shapes their experiences and structures their knowledge was conducted. Finally, an instrument that may be useful in analyzing student talk was examined and applied to a science classroom.

The theoretical work of Vygotsky, Piaget and Bruner has shown the development of the individual mind as it relates to the developmental relationship between thought and language. These theorists have demonstrated that talk can be considered the most important tool for making connections between what is known and what one is trying to know. Talk becomes the medium for processing information. Talk regulates thought.

With this in mind, research is limited in the area of student public talk and the making of meaning. Research has shown that working in small groups to solve problems or to write compositions is a powerful learning tool. Researchers have found that students learn well from each other through their talk. Yet no one has taken a close look at the type of talk that aids students in reaching a higher understanding of a concept.

To evaluate the student talk occurring in groups, I used a model (page 36) developed by Alberta Education (1990). This model is an integrated evaluation and instructional package. The model demonstrates how narrative and spectator role language provide the informing contexts for thought and language required in the participant role. The model is a composite of processes in which language and thought move through an exploring stage, in response to new ideas and language, to a narrating stage, which gives rise to imagining and empathizing. These processes, in turn, initiate an interaction between imagining and empathizing, on the one hand, and abstracting, on the other. The idea here is that students are encouraged to use language to reflect on the significance of what they are learning, thus enhancing their ability to use language for abstraction.



Although the model is cyclic, the process is recursive, with no distinct borders between each role category. The learner can move back to previous states, which in turn drives thought and language forward to increasing levels of refinement at subsequent stages. This model fits into any subject and can be used to evaluate talk and writing.

By understanding the learner's nature, the teacher can assist each student to build on strengths and develop weaker areas. This means that during instructional time, the teacher can intervene, providing the necessary instruction or guidance required by the student. The diagnostic information collected began to give us a profile of individual students. This information helped in selecting activities for subsequent instructional units to build on students' strengths and to overcome weakness. By understanding the importance that student talk plays in learning, teachers should be better at developing appropriate teaching strategies. Knowing how talk functions in learning will help us to help students form concepts, explore symbols and ideas, solve problems and interact with their environment more effectively.

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Book Review

Cheating Lessons: Learning from Academic Dishonesty by James M Lang Harvard University Press 2013 Reviewed by Kerry Rose

Students often cheat because their learning environments encourage them to try. This is the first premise in James Lang's book *Cheating Lessons: Learning from Academic Dishonesty*. Lang is a former assistant director of the Searle Center for Teaching Excellence at Northwestern University, in Chicago, and an English professor at Assumption College in Worcester, Massachusetts. This book was actually written for postsecondary instructors, and because Lang's subject area specialization is English, you may be doubtful of the applicability of his advice for K–12 science classrooms. But I think this is a gem; it is my experience that science teachers appreciate educational ideas backed by evidence, and Lang has done his homework.

This book begins with a concise summary of the research about student academic dishonesty. But more important, after outlining the research on how and when students cheat, dispelling many myths and misconceptions along the way, Lang recounts some simple research-backed strategies that teachers can use to support students when doing the hard work of learning without having to resort to desperate measures like cheating. And, in each chapter, he describes how he has tried these strategies in his own classroom, gradually honing these practices to become more focused and effective over time.

The first third of the book builds a theory about cheating. It has become increasingly apparent, Lang asserts, that dispositional factors (the characteristics of the individual) are less important than the situational or contextual factors into which students are placed. High-stakes, one-shot exams, for example, have been and still are fertile ground for producing cheaters. Even "good kids" cheat—in fact, in some cases high-achievers are *more* likely to be academically dishonest. And sometimes even the teachers cheat. Lang peppers his

chapters with documented stories, recent and historical, that engage as they make his point. He recounts incidents of teacher "eraser parties" held to correct student answers on standardized tests (that were used to rate schools) in the US, and gives historical examples of evidence that ancient Greek Olympic athletes bribed judges and paid competitors to throw matches. But it is the comprehensive summaries of the research into learning and academic honesty that will especially appeal to the science teacher. Lang is able to consider sample sizes, types and methods for gathering evidence in the research he recounts. He is very good at evaluating this evidence and he finds concordance with what many experienced teachers already knew or suspected-that if we want students to be ethical and honest in their work, then as teachers we should be able to design our classrooms and our assessments to send this message and to accept nothing less.

Lang asks some questions that may seem to have obvious answers, but become difficult when carefully considered. For example, we all would probably consider copying the exam answers of another student while writing a test as dishonest, but is it cheating when students work together on homework? Do students know what it means to cheat? Do teachers make it clear what being academically honest means in their classrooms, and if they do, does this make any difference? What are appropriate consequences for academic dishonesty and what messages do these consequences send to the students, their peers and the greater educational community that surrounds them? How important is it that other teachers in your school or department are consistent in how they handle assessments and any academic dishonesty that they experience? The research-based answers to these questions may surprise you.

Many educational advice books give recommendations that are impossible to implement without significant increases in support and funding in classrooms. This book is not one of these. Since Lang is a practising educator, and since he often has very large classes, his suggestions are both practical and, mostly, cost free. In fact, many of the scenarios he describes are examples from science classrooms, where students are frequently asked to solve problems and there often is a "correct" answer.

In the second part of his book, Lang describes how this concrete classroom advice can take many forms; he includes many real-world examples, mostly of small changes classroom teachers can implement that the research has shown to be effective in promoting academic honesty and better learning. In the end, he gives some ideas for what to consider if and when you do experience academic dishonesty in your classroom or in your school, and how these lessons can be genuine turning points for students, teachers and schools.

Although the title implies that the subject of the book is primarily about the terrible experience of confronting academic dishonesty in classrooms, Lang actually builds support here for quite a different premise: that it is possible to design classrooms in which cheating is *not* an issue. Better learning design can lead to better learning outcomes for students, and little to no academic dishonesty is actually a side effect. Lang does a good job of supporting his thesis that great learning classrooms are also those that are free of cheaters, that this is no coincidence and that, regardless of grade level or subject, we can all design our classrooms to become cheat free.